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SPATIAL SPARK JITTER MEASUREMENTS OF HIGHLY CHARGED NUCLEI FOR OPTICAL SPARK CHAMBERS

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Spatial Spark Jitter Measurements of Highly Charged Nuclei for Optical Spark Chambers*

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ABSTRACT

The spatial jitter of sparks about the paths of relativistic nuclei of various charges Z has been measured for optical spark chambers. For normal incidence the jitter measured was consistent with the $1/Z$ dependence expected from diffusion of the ionization electrons.

Many experimenters have utilized optically-viewed spark chambers filled with 90 percent neon, 10 percent helim gas mixture at STP, and with 1 cm gap spacing. Although most experiments are limited in their resolution by alignment and optical calibration uncertainties, the ultimate limit to spark chamber resolution is set by jitter in position of the sparks. The best jitter measurement reported to date is about .18 mm.[1,2] Jitter is adequately explained by diffusion of the electrons, produced by ionization, during the time interval between the incident particle's passage and the actual spark formation.[1] The mean diffusion distance for the centroid of the electrons is inversely proportional to the square root of the number of electrons. Some workers have reduced their jitter by using wider gaps,[3] by pressurizing the gas,[2] or by increasing

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the ionization power of the incident particle.[4] Recently substantial reduction of resolution error has been achieved by the use of liquid xenon.[5] All of these methods reduce the jitter by increasing the number of electrons created. For cosmic ray nuclei experiments, and for experiments at the new heavy-ion accelerators, the large electric charge on a heavy nucleus can be expected to produce substantial reductions in spark jitter for conventional spark chamber systems. In this paper we report the results of jitter measurements on spark chamber photographs of relativistic cosmic rays with various charges. For a relativistic particle of charge Z, the number of ionization electrons produced is proportional to Z^2. Since the spark drift is inversely proportional to the square root of the number of electrons, the jitter should go as $1/Z$. We show that the spark chamber jitter is consistent with the expected $1/Z$ description, for the range $Z = 1$ through 6.

Our balloon-borne magnetic spectrometer for cosmic rays has been described previously.[6] The scintillation counters in our experiment provided unique charge identification for each event. From the 120,000 events exposed in our two balloon flights to 35 km altitude, we selected a sample of events which had unambiguous charge, nearly normal incidence (less than 0.1 radians) to our spark chambers, and a good fit to a rigidity (momentum/charge) above 5 GV/c. For these jitter measurements we accepted only events which had a spark present in every gap of the spark chambers. Figure 1 shows a typical 4-spark segment. The events selected for jitter study were measured on the Powell-Birge group's measuring microscope at the Lawrence Berkeley Laboratory. Each spark was measured four times, and the results were averaged together. Figure 2 shows the deviations of these measurements from the averages. The centering error for a single spark measurement is 1.0 micron on the film, corresponding

to 0.054 mm in the spark chambers. The least count of the microscope was one micron.

The spark locations were corrected for the sweeping of the ionization electrons (empirically determined to be 1/4 of a gap, perpendicular to the spark chamber plates) occurring between the application of a high voltage and spark formation. The four averaged sparks were least-squares fit to a straight line. The root-mean-squared spark jitter was calculated for each segment using the formula

$$\sigma_{rms} = \sqrt{\frac{\sum_{i=1}^{4} (y_i - mx_i - k)^2}{2}}$$

where m is the slope and k the intercept for the best-fit line through the sparks. Figure 3 shows the distribution of σ_{rms} observed for various charges of particles incident. It is clear from figure 3 that the heavily-ionizing particles suffer much less spark jitter than the protons.

In order to unfold the actual spark jitter from the results of figure 3, we removed the expected error from the microscope least count (0.3 microns rms), from the centering error on the four-spark average (0.56 microns rms), from the variations in electron-sweep time (0.25 microns rms), and from a 20 percent variation in spark chamber magnification over the volume of our chambers (0.3 microns rms). Figure 4 shows the resulting jitter values we have measured, as a function of the incident charge. The smooth curve shows the $1/Z$ dependence (normalized to helium) one would expect if the jitter mechanism were dominated by the statistics of electron diffusion. Our results show substantially reduced spark jitter for the more heavily ionizing particles, consistent with the simple diffusion mechanism.

We would like to thank Dr. Robert Ely of the Birge-Powell group for his assistance in getting us set up for our measurements. We also acknowledge useful conversations with Dr. Richard Muller and the support of Professor Luis W. Alvarez.

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FIGURE CAPTIONS

Fig. 1. Photograph of a typical four-spark segment. This particular segment is from a beryllium nucleus track.

Fig. 3. The smooth curves are the best fits to the expected shape for pure Gaussian jitter of the sparks.

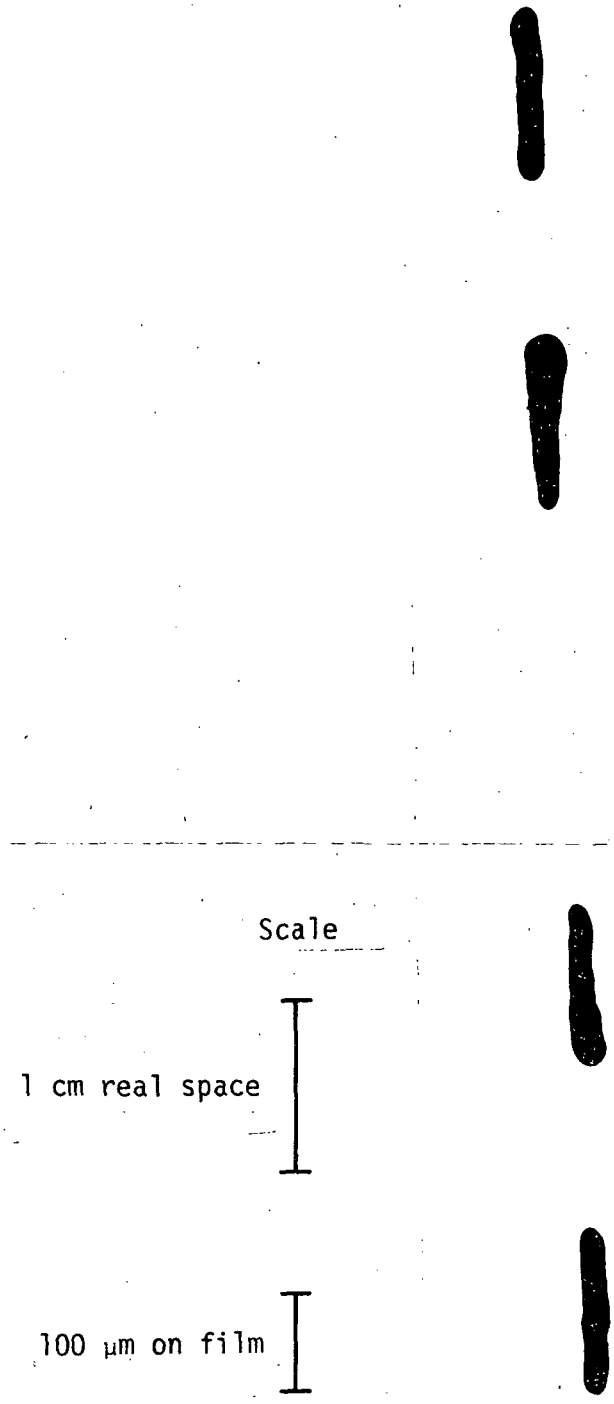

Figure 1

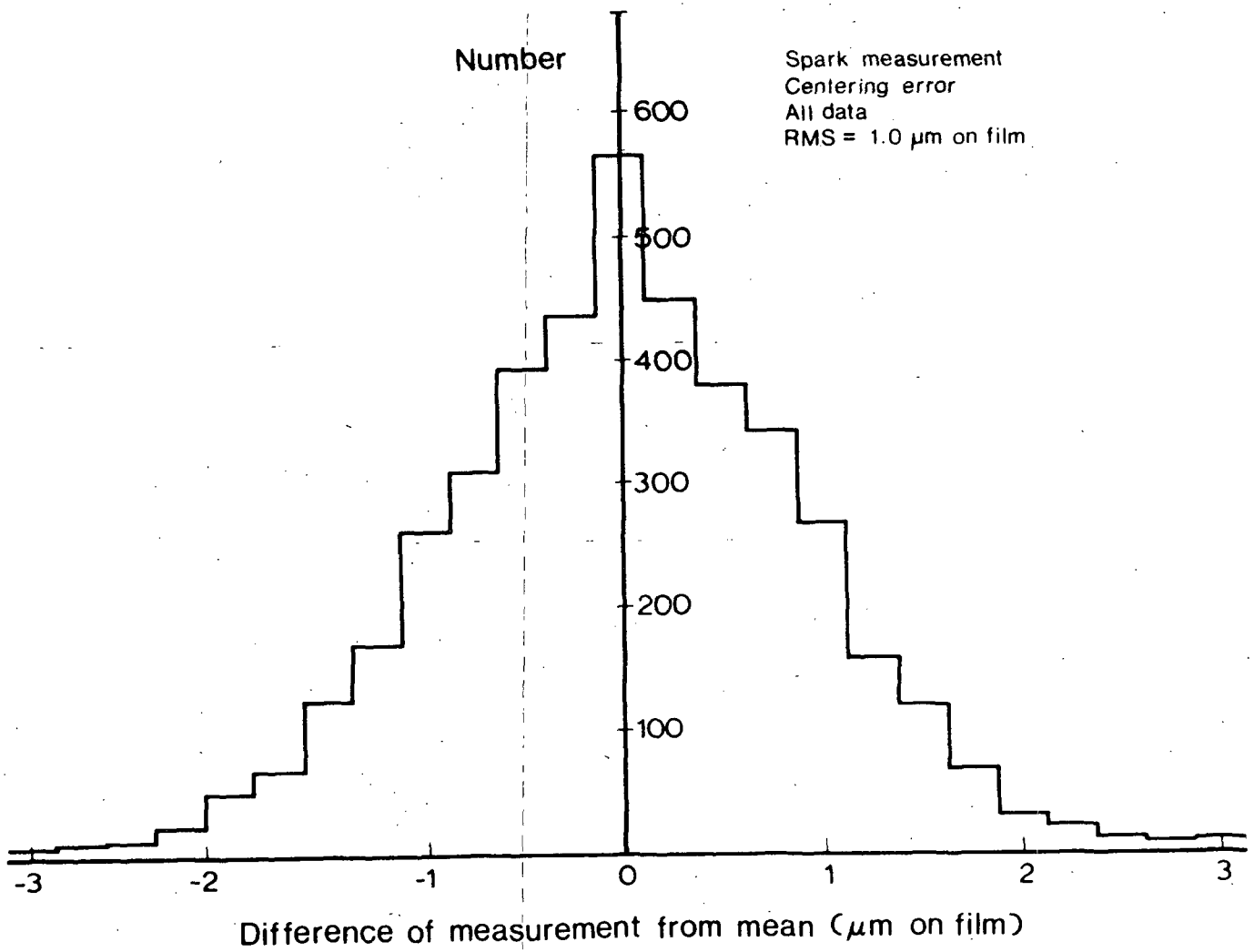
Number
Spark measurement
Centering error
All data
RMS = 1.0 μm on film
600
500
400
300
200
100
-3
-2
-1
0
1
2
3
Difference of measurement from mean (μm on film)

Figure 2

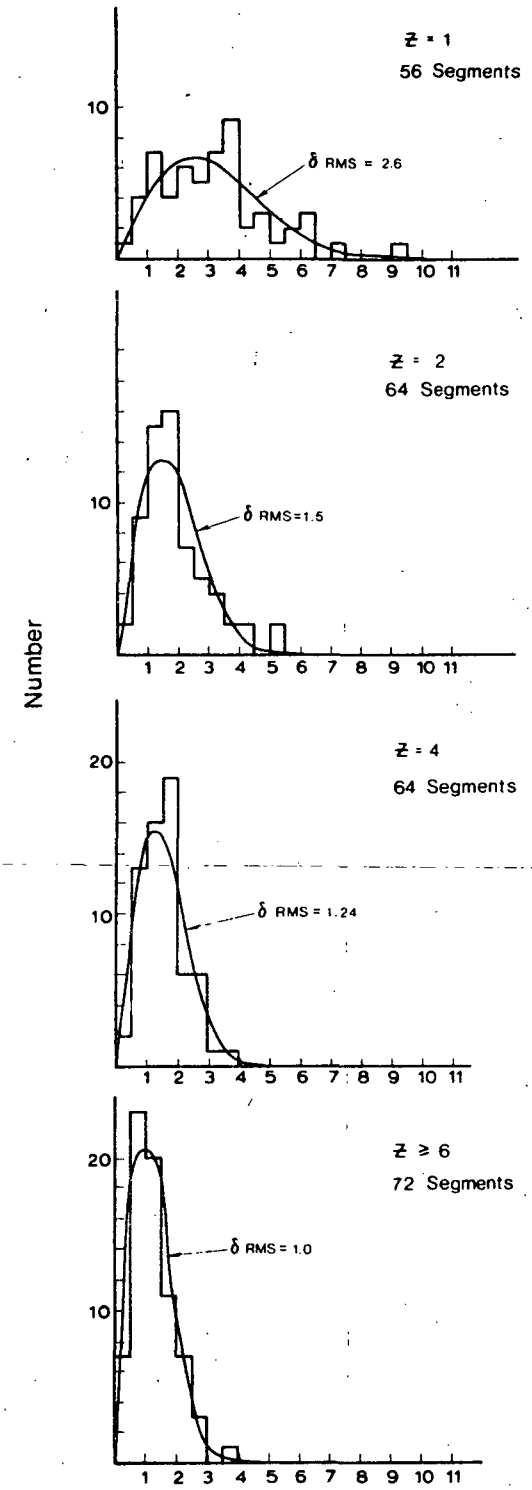
Z = 1
56 Segments
δ RMS = 2.6
Z = 2
64 Segments
δ RMS=1.5
Z = 4
64 Segments
δ RMS = 1.24
Z ≥ 6
72 Segments
δ RMS = 1.0
Number
10
20
1 2 3 4 5 6 7 8 9 10 11
Root mean squared spark deviation (μm on film)

Figure 3

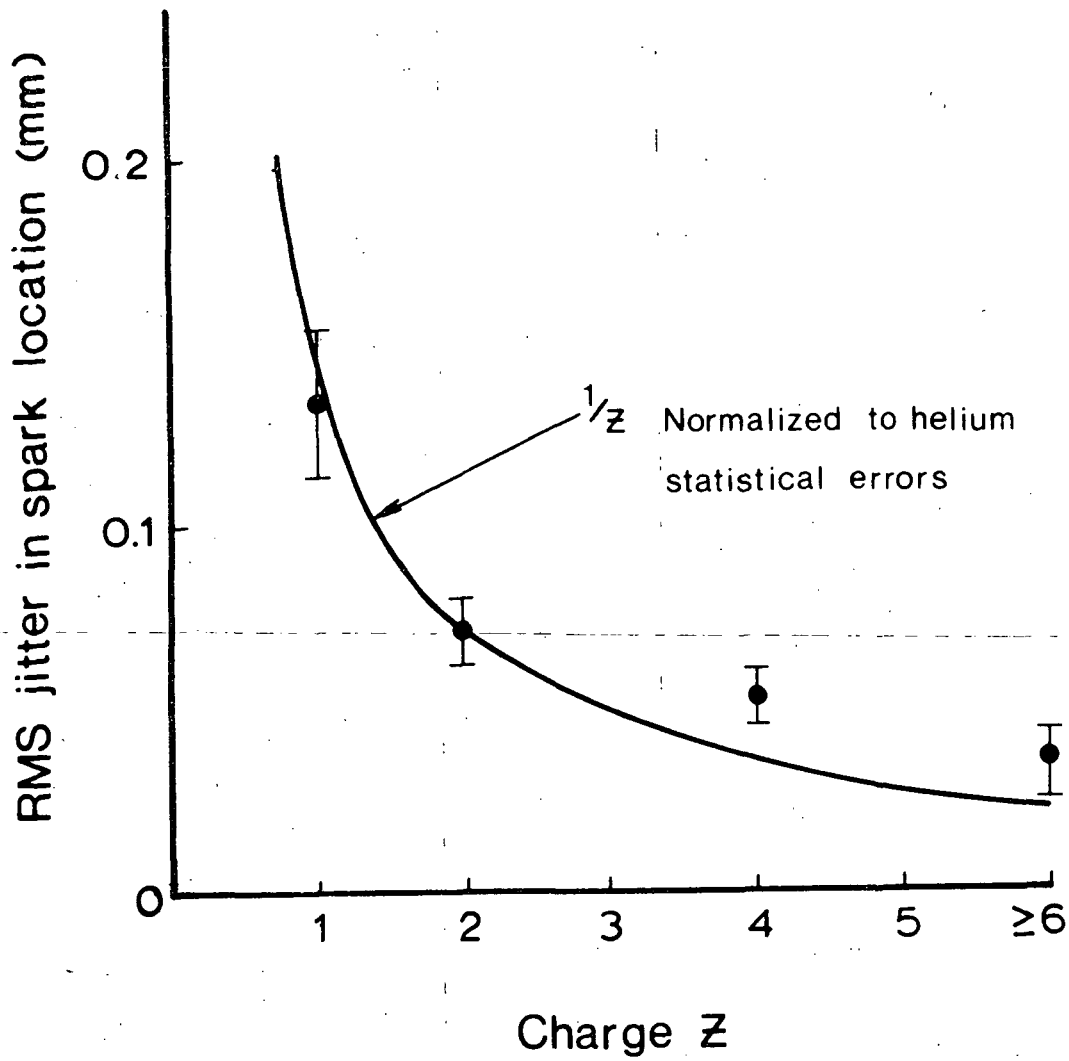
RMS jitter in spark location (mm)
0.2
0.1
0
1
2
3
4
5
≥6
Charge Z
1/Z
Normalized to helium
statistical errors

Figure 4